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09/485525

416 Rec'd PCT/PTO 09 FEB 2000

SPECIFICATION

METHOD FOR THE STATISTICAL MULTIPLEXING OF ATM CONNECTIONS

Ins A ~~The invention is directed to a method according to the preamble of patent claim 1~~.

A number ~~plurality~~ of connection types ~~are defined given connections~~ via which information is ~~are~~ transmitted according to the asynchronous transfer mode (ATM) are known. Connections ~~Thus, on the one hand, connections~~ having strict demands made of the cell delay times are distinguished from connections that do not make strict demands of the cell delay times.

Particularly included among the former are connections with which information is ~~are~~ transmitted with a constant bit rate (CBR) as well as connections via which real time information is ~~are~~ transmitted with a variable bit rate (rt-VBR).

The latter include non-real-time VBR connections (nrt-VBR) or connections via which information is ~~are~~ transmitted with a variable bit rate (available bit rate, ABR) or unspecified bit rate connections (UBR).

The information of all five above connection types is ~~are~~ conducted in ATM cells together ~~in common~~ via virtual paths or, ~~respectively,~~ virtual lines having a predetermined bit rate (bandwidth). In the course of setting up ~~the setup of~~ new connections that have strict demands made of the cell delay times, it is required to calculate the bandwidth ~~that is~~ required for the totality of all connections conducted over a connecting section/connecting line or a virtual path. For calculating an effective bandwidth, it is necessary to determine the rate with which the large cell memory offered for this connection type as well as the other connection types (nrt-VBR, ABR, UBR) is allowed to be emptied.

Upon setup of an ATM connection, the transmitting means must generally inform a higher-ranking control means (all acceptance control) of previously defined parameters. This is required in order to assure the quality

of the connection for all subscribers (quality of service). When, for example, too many cells are transmitted and, thus, the transmission capacity is exceeded, too many cells must be discarded. This, however, must be avoided under all circumstances since discarding cells ~~this all~~ involves a loss of information. To this end, for example, at ~~the demand for~~ a cell loss property ~~properly~~ of 10^{-10} for ~~of~~ a connection ~~exists on the part of standardization authorities~~. For this reason, a calculation is performed ~~already carried out~~ at the call setup to determine ~~as to~~ whether this new connection can be accepted in addition to the connections already existing. When the transmission capacity has already been exhausted, the requested connection is rejected.

A number of transmission parameters are defined for the description of these procedures. These include, for example, the peak cell rate (PCR) defined on a connection. This is ~~thereby~~ a matter of an upper limit for the number ~~plurality~~ of ATM cells that can be transmitted per second via ~~of~~ this connection. Further, the control means is informed of a sustainable cell rate (SCR) by the transmitting means given a connection with variable bit rate. This is the upper limit for an average cell rate with which the cells are transmitted during the existence of the connection. As further parameters, the maximum ~~maximally~~ possible transmission capacity of the connecting line (link cell rate, C) as well as the maximum ~~maximally~~ possible load on the connecting line (p_0) are known to the control means. The former is a matter of a quasi-material ~~quasi material~~ constant of the connecting line, whereas the latter defines a quantity with which the maximally allowable aggregate cell rate on the connecting line is recited. This is usually 95% of the maximum ~~maximally~~ possible transmission capacity of the connecting line. Based on the measure of these parameters, a decision is then made as to whether new connection requests can be accepted or not.

To this end, an algorithm sequence utilized ~~sequences~~ in the higher-ranking control means with which the parameters received from the transmitting equipment are checked. Further, parameters ~~these~~ are compared to parameters that have already been calculated and relate to the momentary load on the connecting line. A decision is then made on the basis of these comparisons as to whether the new connection request is accepted and this connection can still be

permitted. Among other things, the peak cell rate that has already been addressed or the sustainable cell rate are employed as critical parameters.

A number of methods have developed in the prior art for handling these procedures. ~~Let the~~ The sigma rule algorithm ~~be recited here~~ is an example of as a simple method. This algorithm is disclosed in detail in German Patent Application DP 196 49 646.7. ~~A~~ An n^{th} connection is thereby only allowed when the following is valid for the (n - 1) connections already existing plus the n^{th} connection:

$$(a) \qquad \sum_{i=1}^{n} PCR_i \le p_0 \cdot C$$

The connection is likewise allowed when, taking additional properties of the n connections into consideration, as will be explained later, ~~the following condition (b) is met~~ the following condition (b) is met.

$$(b) \qquad \sum_{VC_i \in \text{class } S} SCR_i + g(c, \text{ class } S) \cdot \Big(\sum_{VC_i \in \text{class } S} SCR_i \cdot (PCR_i - SCR_i)\Big)^{1/2} \le p_0 \cdot C - \sum_{VC_i \in \text{class } P} PCR_i$$

whereby $c = p_0 \cdot C - \sum PCR_i$ is the free capacity for class S.

It can be derived from condition (b) that the pending connections are divided into two classes here. At the beginning of the connection setup, ~~thus,~~ the sigma rule algorithm must make a decision as to which of two classes, namely a class S as well as a class P, the potentially newly added ATM connection is to be assigned ~~to~~.

All virtual connections are assigned to class S for which a statistical multiplexing according to the sigma rule algorithm would yield a noticeable gain compared to the peak cell rate reservation algorithm. The following condition must be met as a criterion for this type of connection for the peak cell rate and the sustainable cell rate of all connections to be statistically ~~multiplex~~ multiplexed:

$$PCR/C < 0.03 \quad \text{and} \quad (0.1 \le SCR/PCR \le 0.5)$$

A All other virtual connections are assigned to the class P. These connections particularly include the connections with constant bit rate. Further, all connections are assigned here for which the parameters SCR as well as PCR lie either very close to or very far from one another ~~very close to one another — or very far from one another~~ or that already exhibit a high peak cell rate PCR compared to the overall capacity of the connecting line. A peak cell rate that is greater then 3% of the maximum ~~maximally~~ possible transmission capacity of the connecting line is valid as a criterion for this.

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Further, a factor q can be derived from the condition (b). This factor is dependent both on the class S as well as on the free capacity c of the class S. For a defined class S, the q(c) values must be calculated with a complicated program. In simplifying fashion ~~from dynamics points of view~~, the dependency of the quantity c is estimated by a hyperbola function $q(c)=q_1+q_2/c$.

A In this prior art, an ~~thus, a~~ n^{th} virtual connection VC_n having a defined peak cell rate PCR_n as well as a sustainable cell rate SCR_n is allowed in addition to already existing virtual connections VC_i having the parameters SCR_i as well as PCR_i $(1 \leq i \leq n-1)$ on a connecting line when conditions (a) or (b) are met.

According to the condition (a), a check is carried out to see whether the sum of the peak cell rates of all n connections on the connecting line is equal to or less than the maximum ~~then the maximally~~ possible transmission capacity on the connecting line. When this is the case, then the n^{th} virtual connection can be accepted and the interrogation of condition (b) is superfluous. When this is not the case, then a check is carried in condition (b) to see whether the upper estimate of the average value of the sum of the peak cell rates of all connections of the class S together with a cell rate that is calculated from the burst nature of all connections of the class S is less than ~~then~~ or equal to the cell rate that is available currently for class S connections. When this is the case, then the n^{th} virtual connection is accepted; otherwise, it is rejected.

A In this prior art, the first class S is, in turn, subdivided into further sub-classes S_1, S_2 or S_3 in order to achieve an even finer classification. In case

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of the arrival of a new connection request, ~~thus~~ the sigma rule algorithm must check based on the criterion of determined interrogation criteria to see which of the sub-classes this new connection is to be assigned ~~to~~. The most beneficial sub-class S_x is then automatically selected. A sub-class S_x is thereby defined via a lower limit or, respectively, upper limit of the peak cell rate PCR as well as of the relationship of the transmission parameters SCR/PCR.

Equation (b) thus experiences a modification as shown in Equation (c), by the addressed sub-classes S_k, P_k

$$(c) \qquad \sum_{VC_i \in S_k} SCR_i + q(c, S_k) \cdot \sqrt{\sum_{VC_i \in S_k} SCR_i \cdot (PCR_i - SCRi)} \le c$$

whereby $c = p_0 \cdot C - \sum_{VC_i \in P_k} PCR_i$ is the free capacity for the class S.

The q factor thus derives as $q(c, S_k) = q1_{S_k} + q2_{S_k} / c$.

This connection acceptance algorithm according to this prior art is ~~thus~~ in the position of deciding whether a predetermined bandwidth, ~~for example~~ (e.g., the bandwidth of a virtual path or of a ~~line~~ line), is adequate overall for a group of connections. Since such acceptance algorithms supply a yes/no decision as a result as to whether or not a connection is to be accepted ~~or not~~, they are not directly suited for the calculation of the effective bandwidth for a group of connections.

The effective bandwidth required for a group of connections according to the used sigma rule acceptance algorithm could fundamentally be determined with arbitrary precision by an iterative approximation method. The problem of this method, however, is ~~comprised therein~~ that the acceptance algorithm would have to be multiply run ~~per~~ for each connection setup and, thus, would require an extremely great amount of processor capacity.

European Patent Application EP 0 673 138 A2 discloses a method of how a plurality of connections can be conducted over a common

connecting section. Upon arrival of a connection request, a check is thereby carried out to see if adequate bandwidth is still available for accepting this connection. When this is the case, the connection is accepted; otherwise, it is rejected. The calculation of an effective bandwidth, however, is not addressed here.

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International Application WO 97/01895 likewise discloses a method of how pending connections are conducted via common connecting sections. The goal of such an algorithm, however, is only to accept or, ~~respectively~~, reject the connection based on the criterion of the remaining bandwidth.

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~~The invention is based on the object of disclosing a way of how an acceptance algorithm is to be fashioned such that a bandwidth representative for all connections can be calculated in an efficient way.~~

Ins ~~Proceeding on the basis of the features recited in the preamble of patent claim 1, the invention is achieved by the features of the characterizing part~~. as

What is particularly advantageous ~~for~~ in the invention is that the sigma rule algorithm is employed as an acceptance algorithm. The bandwidth, proceeding from an initial value, is determined step-by-step with the setup/release of connections. The sigma rule algorithm is started at every step and, in addition to supplying a yes/no decision, supplies an estimate of the bandwidth based on the prescription of acceptance ~~criteria, a~~ criteria and a conservative traffic parameter value of a class-specific bandwidth is added or, ~~respectively,~~ subtracted. The conservative traffic parameter value is thereby constructed differently in the case of the connection setup than in the case of the connection release. When the sigma rule algorithm determines that the conservative estimate with respect to the bandwidth would be adequate, then a more aggressive traffic parameter value is added to or, ~~respectively,~~ subtracted from the class-specific bandwidth. Here, too, the more aggressive traffic parameter value is fashioned differently in the case of the connection setup than in the case of the connection release.

Ins ~~Advantageous developments of the invention are recited in the subclaims~~. as

~~The invention is explained in greater detail below with reference to an exemplary embodiment~~.

~~Shown are~~:

~~Fig. 1 a flow chart according to the inventive method~~;

~~Fig. 2 a flow chart according to the inventive method~~.

~~Fig. 1 shows a flow chart of the inventive method. The initially described sigma rule algorithm SR of the prior art is employed as acceptance algorithm. In accord therewith, additional status variables are introduced in addition to the status variable carried in the sigma rule algorithm SR. What are thereby involved are a matter of the status variables~~ ~~c^S_k, c^P_k and c^{eff}_k~~:

The status ~~variables~~ variable c^S_k is a matter of the effective bandwidth of the virtual connections that are to be assigned to one of the classes S_k according to the sigma rule algorithm SR. The status ~~variables~~ variable c^P_k indicates the sum of the peak cell rates PCR of all virtual connections in the class P_k, whereas the status ~~variables~~ variable c^{eff}_k is defined as effective bandwidth of all connections with reference to the classes k. ~~What thus~~ The relationship that follows is:

$$(1) \quad c^{eff}_k = c^S_k + c^P_k$$

Given (n-1) existing connections VC_i with the parameters PCR_i, SCR_i, a calculation is then carried out for a connection setup to see whether 1) the new connection VC_n can be accepted or not; and 2) the effective bandwidth c^{eff}_k that ~~are [sic]~~ is to be reserved for the (n-1) existing connections VC_i including the newly added connection VC_n.

In a first step, a check is first carried to see whether the new connection VC_n to be potentially accepted can be assigned to one of the classes S_k or P_k. For example, let it be assumed that this can be assigned to one of the classes S_k. In this case, a check is carried out to see whether the following condition is met for all virtual connections VC_i, including the connection to be potentially added:

$$(2) \quad \sum_{VC_i \in S_k} SCR_i + q(c^{S_K}+SCR_n, S_k)\cdot\sqrt{\sum_{VC_i \in S_k} SCR_i \cdot (PCR_i - SCR_i)} \le c^{S_K} + SCR_n$$

In the above equation, Equation (c) is taken as the basis and the variable c employed therein is replaced by the bandwidth c^S_k reserved for the (n-1) connections plus the average sustainable cell rate SCR_n that is to be reserved for the n^{th} connection VC_n to be potentially accepted. As can be seen according to Fig. 1, the method is started with a value $c^S_k = 0$.

A strict application of condition (2) likewise yields a bandwidth that is greater than the sum of the peak cell rate PCR_n of all connections. Since the sum of all added, effective bandwidths, however, is never allowed to lie above the sum of its peak cell rates PCR_n, condition (2) is modified in such a way that

$$(3)\quad \min\left[\sum_{VC_i \in S_k} SCR_i + q(c^{S_k}+SCR_n, S_k)\cdot\sqrt{\sum_{VC_i \in S_k} SCR_i \cdot (PCR_i - SCR_i)},\ \sum_{VC_i \in S_k} PCR_i\right] \leq$$

$$c^{S}_{k} + SCR_n$$

is taken. ~~A security in the estimate is thus established.~~ Thus, reliability in the estimate is established.

When the above condition applies, then the effective bandwidth employed up to ~~then~~ that point plus the sustainable cell rate SCR_n allowed for the n^{th} connection VC_n is taken as ~~new~~ the new, effective bandwidth c^{S}_{k}. As a result thereof, the following ~~derives~~ condition applies:

$$(4)\quad c^{S_k} := c^{S_k} + SCR_n$$

When the condition (3) is not met, the effective bandwidth employed up to ~~then~~ that point plus the peak cell rate PCR_n allowed for the n^{th} connection VC_n is taken as ~~new~~ the new, effective bandwidth c^{S}_{k}. Accordingly, the following condition applies:

$$(5)\quad c^{S_k} := c^{S_k} + PCR_n$$

When the new connection VC_n to be potentially added is to be allocated to one of the classes S_k, a value for the effective bandwidth c^{eff}_{k} has thus been found.

When the new connection VC_n to be potentially added cannot be assigned to one of the classes S_k, it is automatically assumed that it is to be allocated to one of the classes P_k. The following thus derives:

$$(6)\quad C^{P_k} := c^{P_k} + PCR_n$$

Upon employment of Equation (1), the effective bandwidth c^{eff}_{k} can then be calculated as follows:

$$c^{eff_k} = c^{S_k} + c^{P_k}$$

An effective bandwidth has thus been found for the case of a connection setup.

Subsequently, it then must also be determined whether the new connection VC_n can be accepted. To this end, the condition

$$c^{eff_k} \leq Po \cdot C$$

must be met.

It is assumed below according to Fig. 1 that a connection release is to be implemented. It is thereby assumed that a connection VC_n is released given n existing connections VC_i having the parameters PCR_i, SCR_i.

Given release of the connection, a check is first carried out to see whether this ~~appertaining~~ pertaining connection VC_n was allocated to one of the classes S_k. In this case, an interrogation criterion is applied to all remaining virtual connections VC_i (accept the connection VC_n) according to condition (7):

$$(7) \quad \sum_{VC_i \in S_k} SCR_i + q(c^{S_k} - PCR_n, S_k) \cdot \sqrt{\sum_{VC_i \in S_k} SCR_i \cdot (PCR_i - SCR_i)} \leq c^{S_k} - PCR_n$$

A strict application of condition (7) now potentially yields a bandwidth for the remaining (n-1) connections that is greater than the sum of the peak cell rates of the connections. Condition (7) is therefore to be modified in such a way that

$$(8)\quad \min\left[\sum_{VC_i \in S_k} SCR_i + q(c^{S_k} - PCR_n, S_k) \cdot \sqrt{\sum_{VC_i \in S_k} SCR_i \cdot (PCR_i - SCR_i)},\ \sum_{VC_i \in S_k} PCR_i\right] \le c^{S_k} - PCR_n$$

derives.

When the above condition applies, then the effective bandwidth applied up to ~~then~~ this point minus the peak cell rate PCR_n allowed for the n^{th} connection VC_n is taken as ~~new~~, effective bandwidth $c^s{}_k$. Deriving therefrom is:

$$(9)\quad c^{S_k} := c^{S_k} - PCR_n$$

When condition (8) is not met, ~~then~~ the effective bandwidth employed up to ~~then~~ this point minus the sustainable cell rate SCR_n for the n^{th} connection VC_n is taken as the new effective bandwidth $c^s{}_k$.

$$(10)\quad c^{S_k} := c^{S_k} - SCR_n$$

A value for the effective bandwidth $c^{eff}{}_k$ has been found for the released connection VC_n that was allocated to one of the classes S_k.

When the released connection VC_n was not allocated to one of the classes S_k, it is automatically assumed that it was allocated to one of the classes P_k. The following thus derives:

$$(11)\quad c^{P_k} := c^{P_k} - PCR_n$$

Upon application of Equation (1), the effective bandwidth $c^{eff}{}_k$ can then be calculated as follows:

$$c^{eff_k} = c^{S_k} + c^{P_k}$$

An effective bandwidth has thus been found for the case of a connection release.

A In one ~~development~~ embodiment of the invention, it ~~is provided to replace~~ Equation (10) ~~with~~ can be replaced with:

$$(12)\quad c^{S_k} := \min\left[c^{S_k} - SCR_n, \sum_{VC_i \in S_k} PCR_i\right]$$

Upon release of connections that were allocated to one of the classes S_k, the value of the class-specific bandwidth $c^{S}{}_{k}$ is thus upwardly limited by the sum of the peak cell rate of all connections allocated to the classes S_k. The corresponding conditions are illustrated at step S shown in Fig. 2

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